Gas Turbine Systems for the 21st Century

1999 IGTI TurboExpo
Indianapolis, IN

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DOE-FETC
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DOE-Office of Energy Efficiency and Renewable Energy

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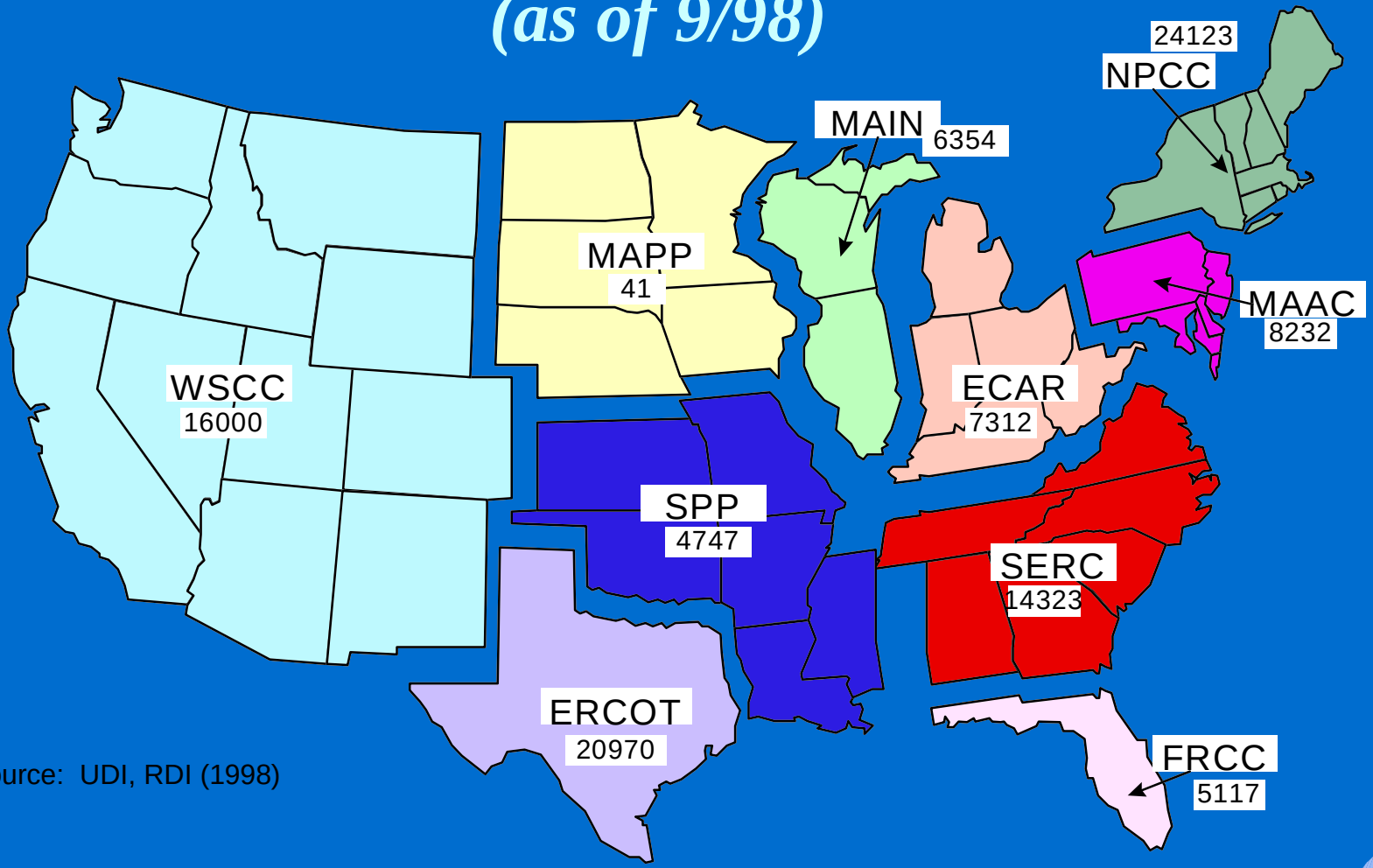
Announced Total Capacity (MW) Additions by NERC Region (as of 9/98)



Source: UDI, RDI (1998)

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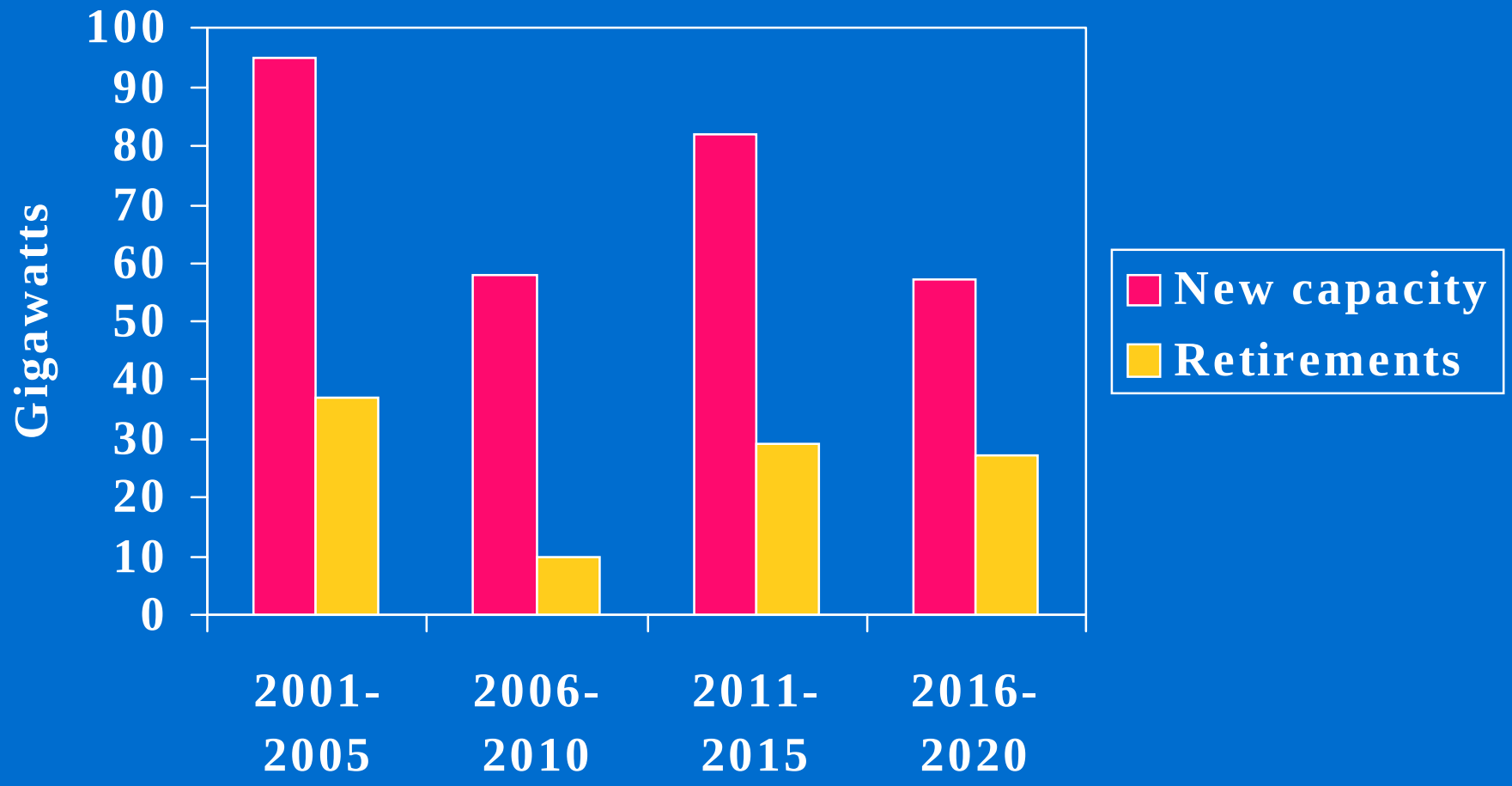
Potential Need for New Capacity



Source: Annual Energy Outlook 1998

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Objective: ATS Program

- **By 2000 develop ATS for utility and industrial applications that are:**
  - Ultra-high efficiency: >60% for utility scale systems
    15% improvement for industrial system
  - Super-clean: NOx <10 ppm
  - Cost of electricity 10% lower
  - Fuel flexible: Gas primary focus

Leapfrog in Turbine Performance

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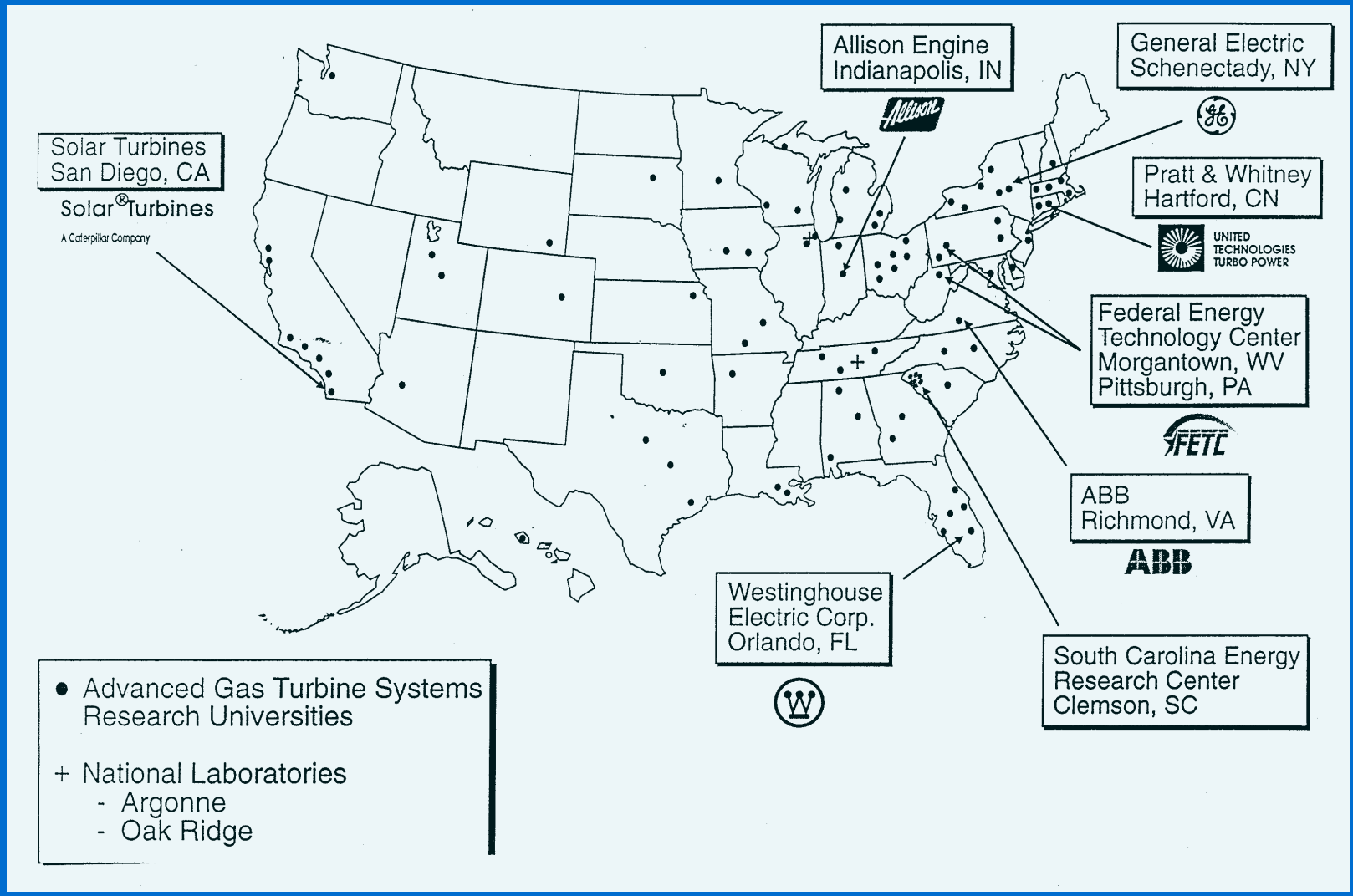
The Advanced Turbine System Program Participants

A Consortium of Universities, National Laboratories, U.S. Government, and Private Industry in 37 U.S. States



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The ATS Program Today

System Studies
(Phase I)

Concept Development
(Phase II)

Technology
Readiness Testing
(Phase III)

ABB

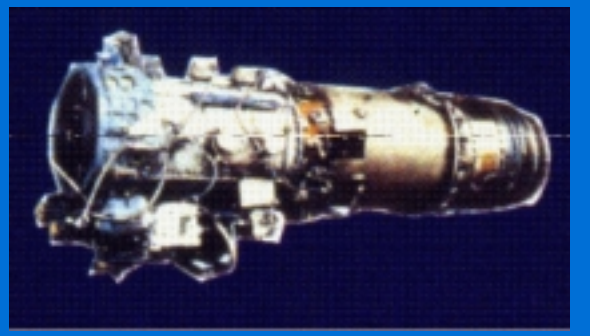
UNITED TECHNOLOGIES TURBO POWER

Solar® Turbines
A Caterpillar Company

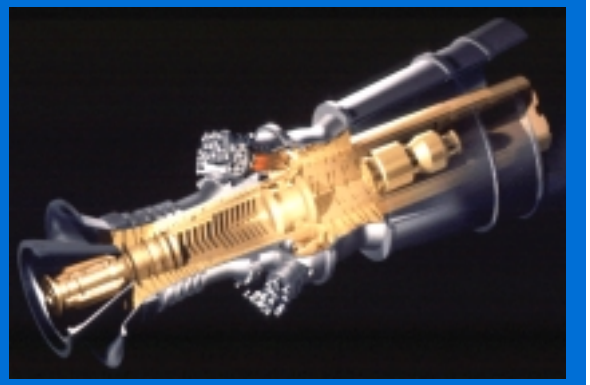
Allison

Manufacturer
Full-Scale Testing/
Performance
Validation

2000



Industrial



Utility

Industry/University Consortium FETC Materials Coal & Biomass

Technology Base Research

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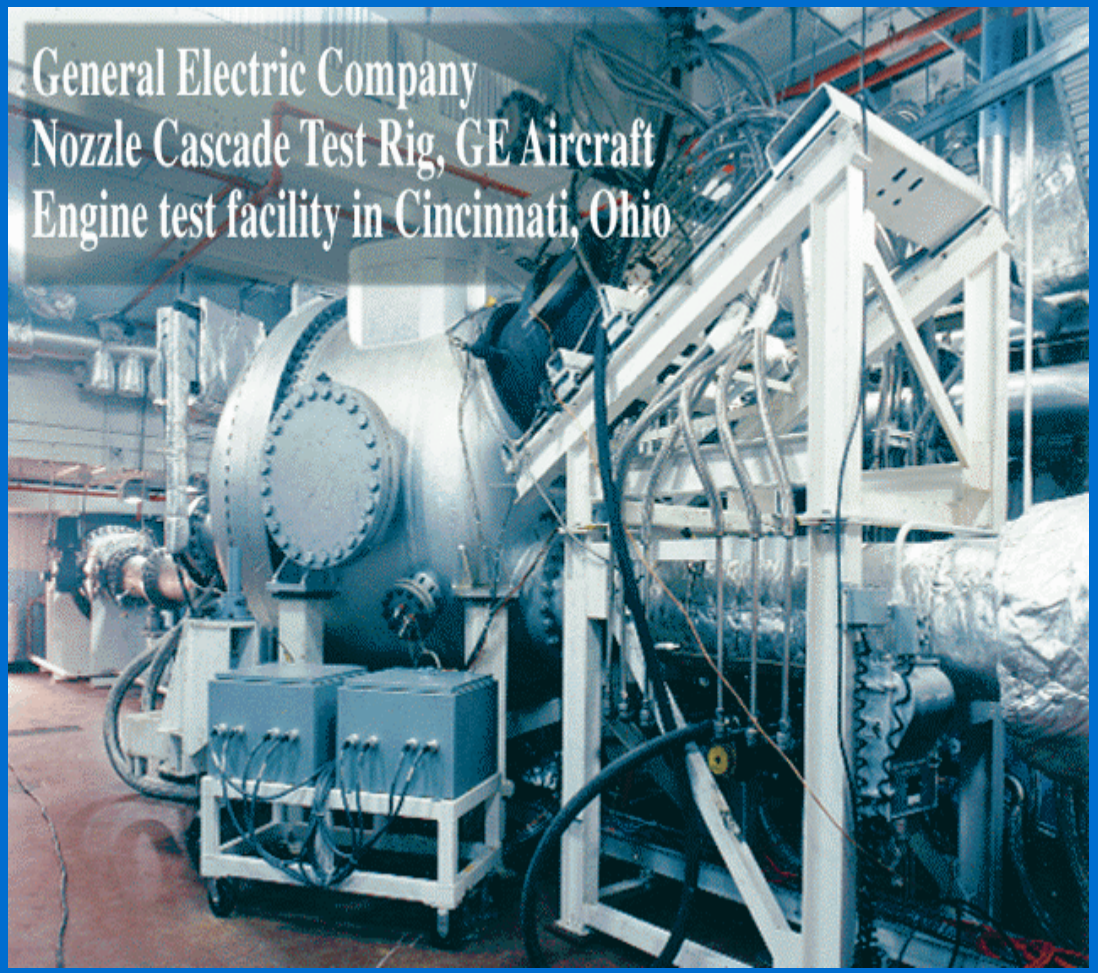
General Electric Company

Turbine System Development and Testing

- **Completed full scale testing of 9H(50Hz)ATS, Greenville SC**
- **Complete 7H(60Hz) ATS testing in 2000, Greenville SC**
- **Conduct pre-commercial demonstration of 7H ATS in 2001**

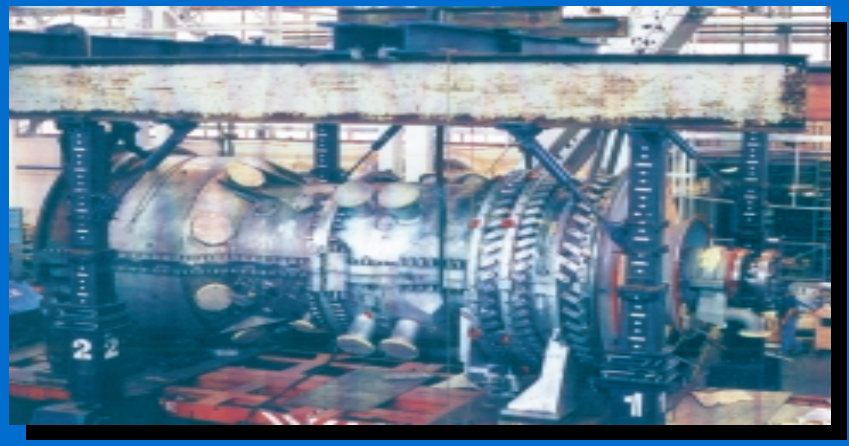
General Electric Company
Validation and Testing Program

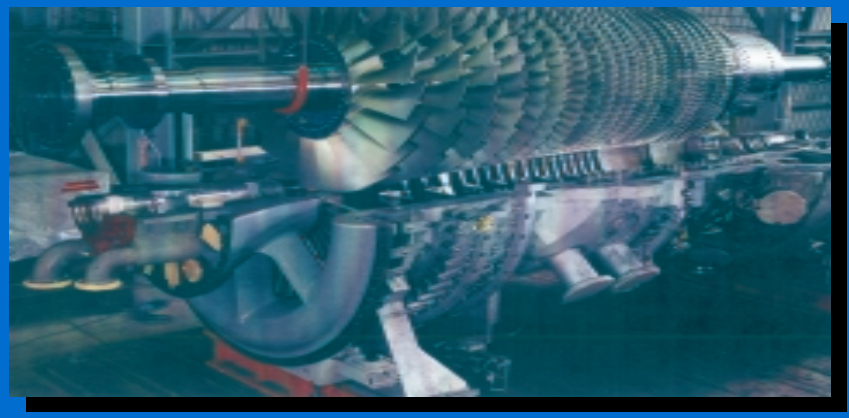
- Full pressure combustion system at GE High Pressure Test Facility, Ohio
- Sub-scale compressor testing- GE Aircraft-, Lynn MA
- Steam cooled nozzle at GE High Pressure Test Facility, Ohio



Siemens-Westinghouse Power Corporation
Turbine System Development and Testing

- **Continue field testing of catalytic combustion and steam cooled systems on 501G**
- **Develop steam cooled vanes and test on 501GS power plant in 2001**
- **Manufacture 501 ATS and ship to customer site in 2002**
- **Conduct pre-commercial demonstration on 501ATS in 2002**





Siemens-Westinghouse Power Corporation

Validation and Testing Program

- **Ohio State University Aerodynamic development testing on 1/3 scale model rig**
- **Catalytic combustion field testing on existing turbine**
- **Full scale steam cooled vane testing at Arnold Airforce Base**

Manufacturing Materials

Oak Ridge National Laboratory-FETC

Projects with: GE-PCC Airfoils, Siemens-Westinghouse, Howmet-GE-Solar

- **Utility scale single crystal blades-reduced sulfur/no grain defects**
- **New core materials and processes, NDE**
- **Grain orientation control**
- **New projects - cost reduction; increased yield rates**

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Solar Turbines

Technology R&D and Demonstration Program

- **Mercury 50- 1st engine in production**
- **demonstration site is Rochelle Foods/Rochelle Municipal Utilities**
- **40% + efficiency, single digit emissions**
- **4.3 MW output**

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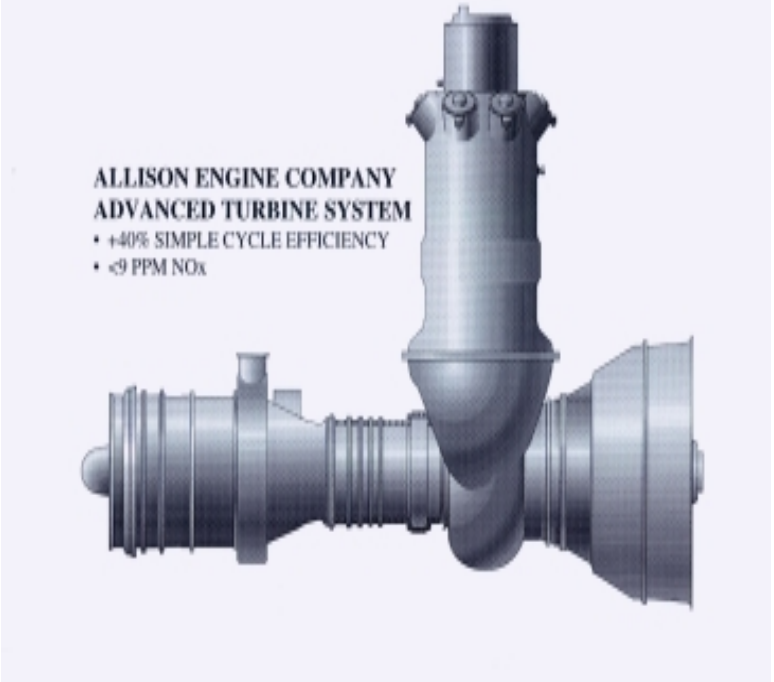
Allison Engine Company

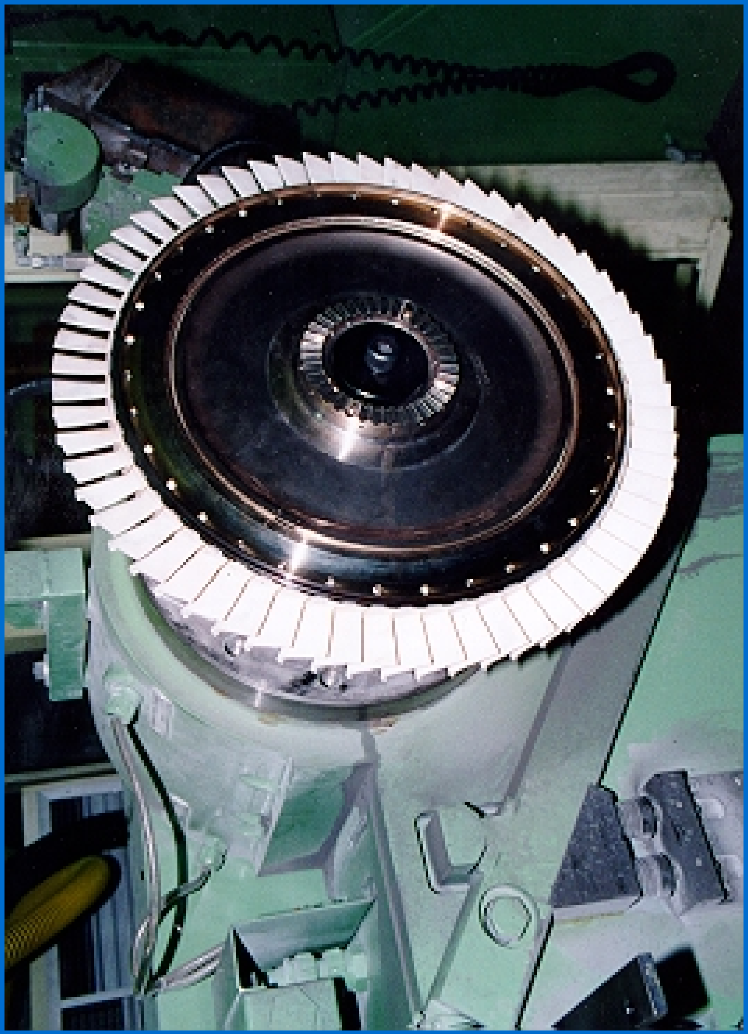
Technology R&D Program

- **Focus on advanced technology to meet ATS development goals**
- **ceramic vanes**
- **low emissions combustion**
- **technology to advance current engines to ATS goal vs. new engine development**



Ceramic Stationary Gas Turbine Developments-ARCO Western Energy

- **4000 hours of ceramic blades**
- **CFCC combustion liner testing for >5000 hours**
- **First stage nozzle SN88 installed**
- **total testing time accumulated 4000 hours**



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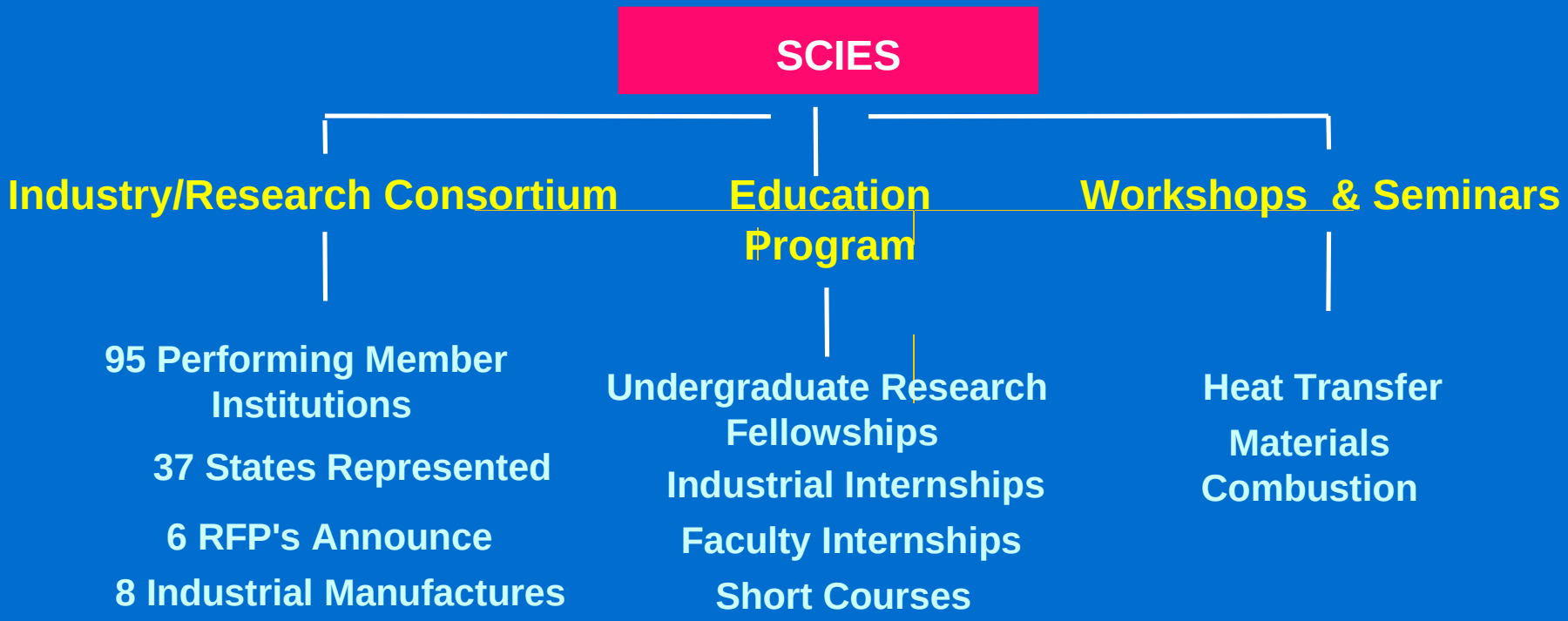
Industry/University Consortium



Industry/ University Consortium-
South Carolina Institute for Energy Studies

- **A consortium of 95 U.S. universities in 37 states**
- **51 ongoing projects with universities**
- **Topical Areas - Heat Transfer, Aerodynamics, Combustion, Materials**
- **Workshops, Internships, Sabaticals**

Next Generation Turbine and Engine Systems

- ***Fuel Cell Hybrid Systems(engines and turbines)***
  - High efficiency, low emissions
  - Distributed generation
  - Long Term Vision 21 systems
- ***Flexible Gas Turbine Systems***
  - Flexibility - operation, fuel, modularity
  - Efficiency improvements for existing fleet of power plants(coal, gas, oil)

Next Generation Turbine and Engine Systems

- ***Vision 21-High Efficiency Engines and Turbines***
  - Advanced turbine cycles
  - Ultra high temperature, pressure
  - Reheat and/or inter-cooling
    Hydrogen/CO2 turbines
- ***Advanced Reciprocating Engine Systems***
  - Distributed Power
  - Ultra high efficiency
  - Lowest emissions technology
  - Natural Gas fueled

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Rationale for Vision 21

- Removes environmental barriers to fossil fuel use
- Keeps electricity costs affordable
- Produces useful coproducts, e.g. liquid transportation fuels, at competitive prices
- Continues U.S. leadership role in clean energy technology
- Provides the most certain route to achieving our energy, environmental, and economic objectives

Vision 21 Goals

- **Develop advanced technology modules for a new fleet of 21st century energy plants tailored to market demand:**
  - efficiency (to electricity)
    > 60 % on coal; > 75% on gas
  - overall thermal efficiency of 85 - 90%
  - near zero pollutant emissions
  - lower cost of electricity and fuels than today
  - cost effective management of carbon emissions

- **Establish mechanisms for deploying these advanced technologies, including industry and government partnerships**

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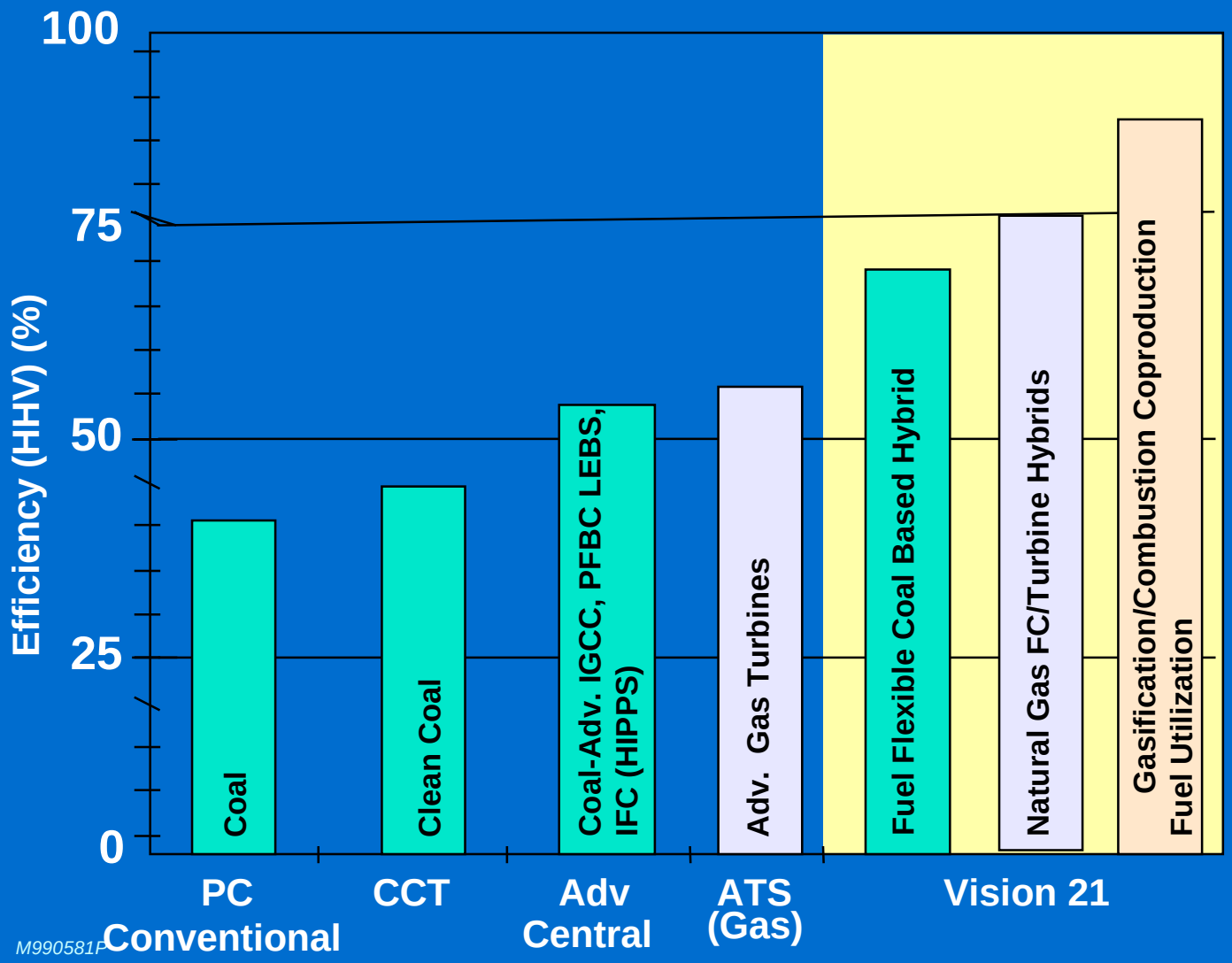
Fossil-Based Power Systems Efficiencies



- Conventional new power plants operate at 35-37% efficiency
- CCT program has demonstrated plants with 38-40% effic.
- "Nth" of a kind CCT units will improve to 45-50% efficiency
- Vision 21 plants capable of 60-65% efficiency on coal, 75% on gas, 85% in coproduction

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Next Generation System Goals by year 2010

System Size- 30-150MW

Improved Design Efficiency	45-50%
Cost of Electricity	15-20% below market
Service life	No greater than ATS
Reduced carbon emissions	Retrofitable
Market Penetration	25% of 2010 market
Dispatch flexibility	400 starts per year
Nox emissions	Meet any 2010 requirement
Reduce O&M costs	15% reduction from comparable product
Reduce capital costs	15% reduction from comparable product

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Vision 21 Fuel Cell/GT Cycle

Plant Performance Summary

Gasifier	Destec
Coal Input to Gasifier, lb/hr	256,142
Thermal Input, MW_t	875.8
HP SOFC Module, MW, dc/ac	189.4/182.8
LP SOFC Module, MW, dc/ac	121.4/117.2
Gas Turbine, MW	133.7
Steam Turbine, MW	118.0
Fuel Expander, MW	9.6
Gross Power, MW	561.3
Auxiliary Power MW	40.4
Net Power, MW	520.9
Efficiency, % HHV	59.5

Next Generation Systems Will...

- **Build on success of ATS program**
- **Result in significant air emissions reductions**
- **Accelerate the overall efficiency increase of the existing and new power generation fleets in the U.S.(coal,oil,gas)**
- **Develop an effective pathway to Vision 21 systems**